Intraseasonal Variability of the Equatorial Atlantic Ocean

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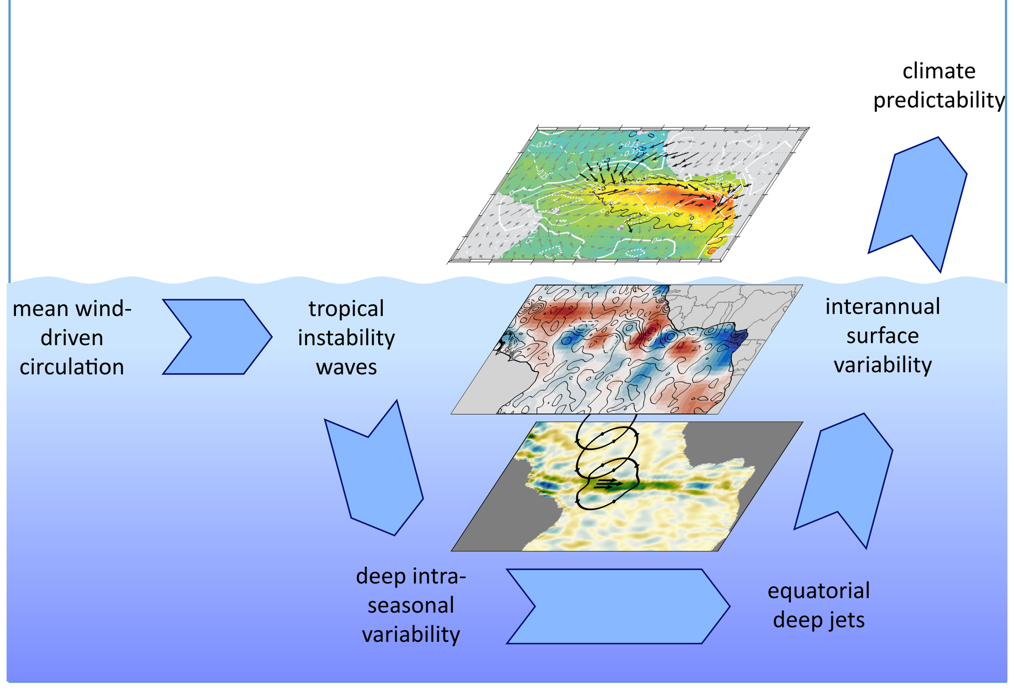
Motivation

- The Equatorial Atlantic circulation is characterized by zonal currents varying on seasonal to interannual timescales; enhanced energy in the **intraseasonal frequency range (20-70 days)** is dominated by meridional velocity variability.
- Tropical Instability Waves (TIWs) are the dominant intraseasonal variability near the surface with **intraseasonal energy observed to penetrate into the deep ocean.**
- It is suggested, that **part of the TIW energy radiates down- and eastward as beams of monthly Yanai waves** to supply energy for the maintenance of zonal circulation variability (*Ascani et al., 2015*), possibly affecting tropical Atlantic variability (*Brandt et al., 2011*).

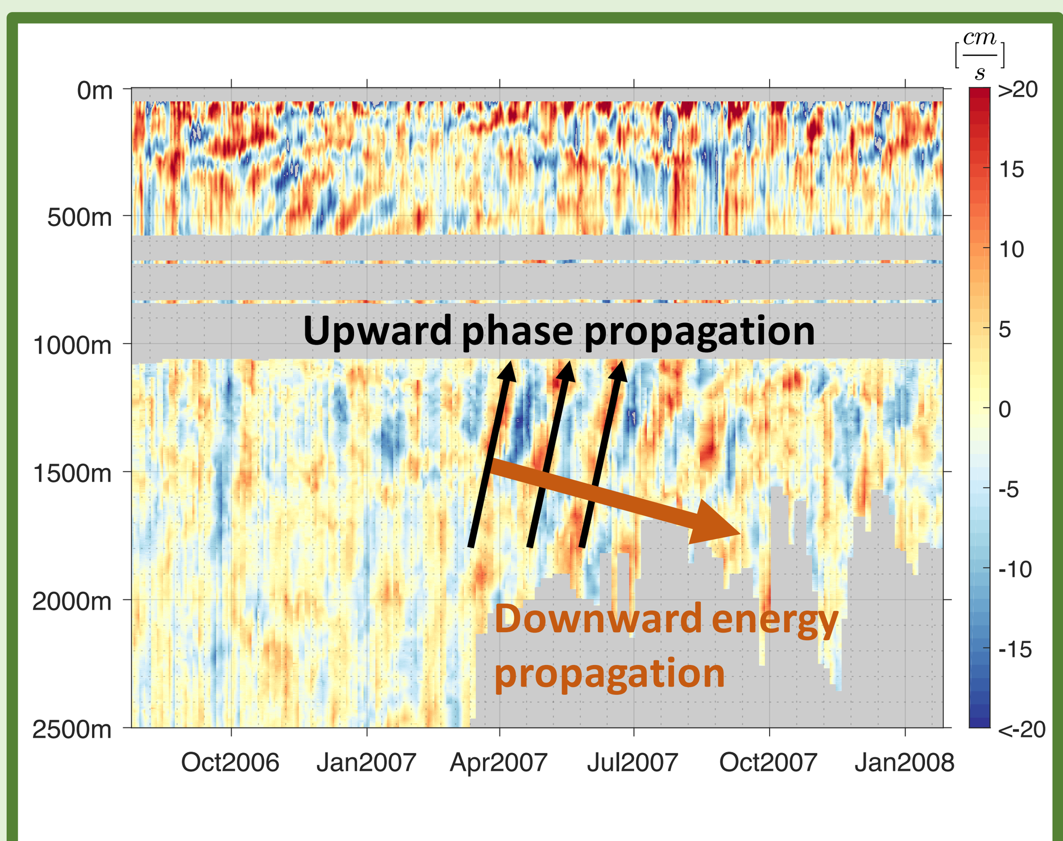
Possible impact on tropical Atlantic variability



Results

- Comprehensive **observational evidence of deep equatorial intraseasonal variability (DEIV)** including the downward energy propagation of intraseasonal waves derived from long-term mooring data is presented.
- Intraseasonal energy undergoes an annual intensification in boreal summer close to the surface and also exhibits a **pronounced seasonal cycle at depth**.
- A vertical mode decomposition of both horizontal velocity components suggests**,** that the **intraseasonal frequency range is dominated by Yanai waves of baroclinic modes 2-10**.

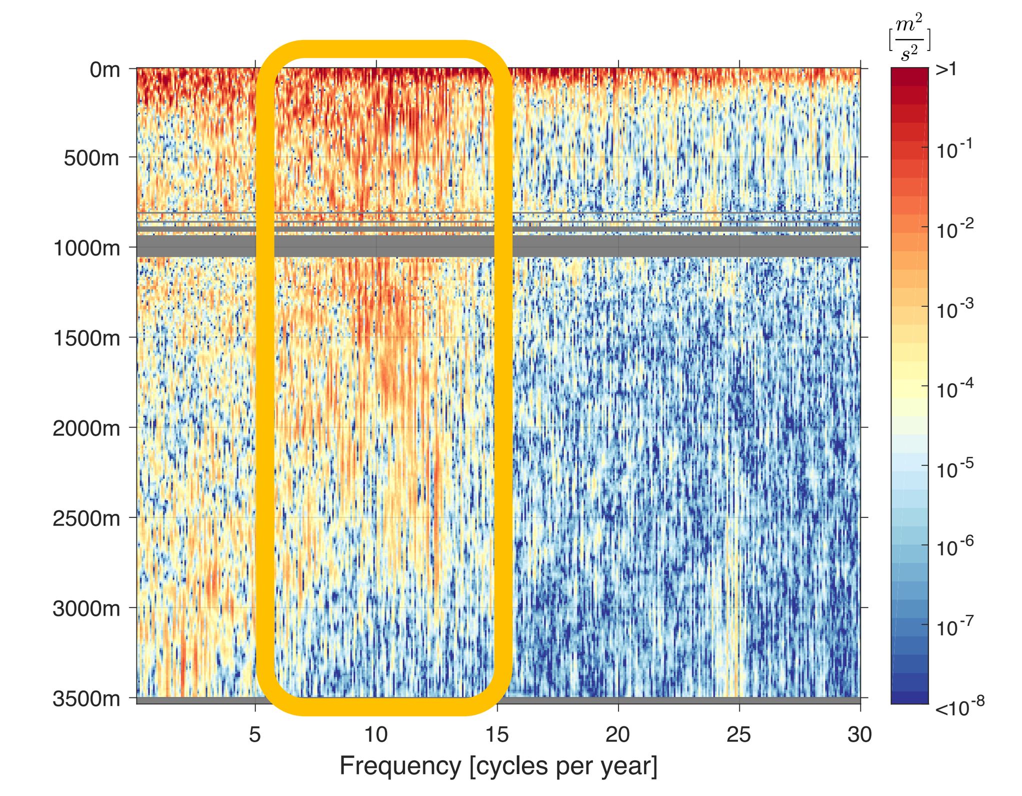
Vertical Energy Distribution



Moored meridional velocity at 23°W (July 2006 to January 2008). Positive (negative) values represent northward (southward) velocities, whereas grey areas show missing data .

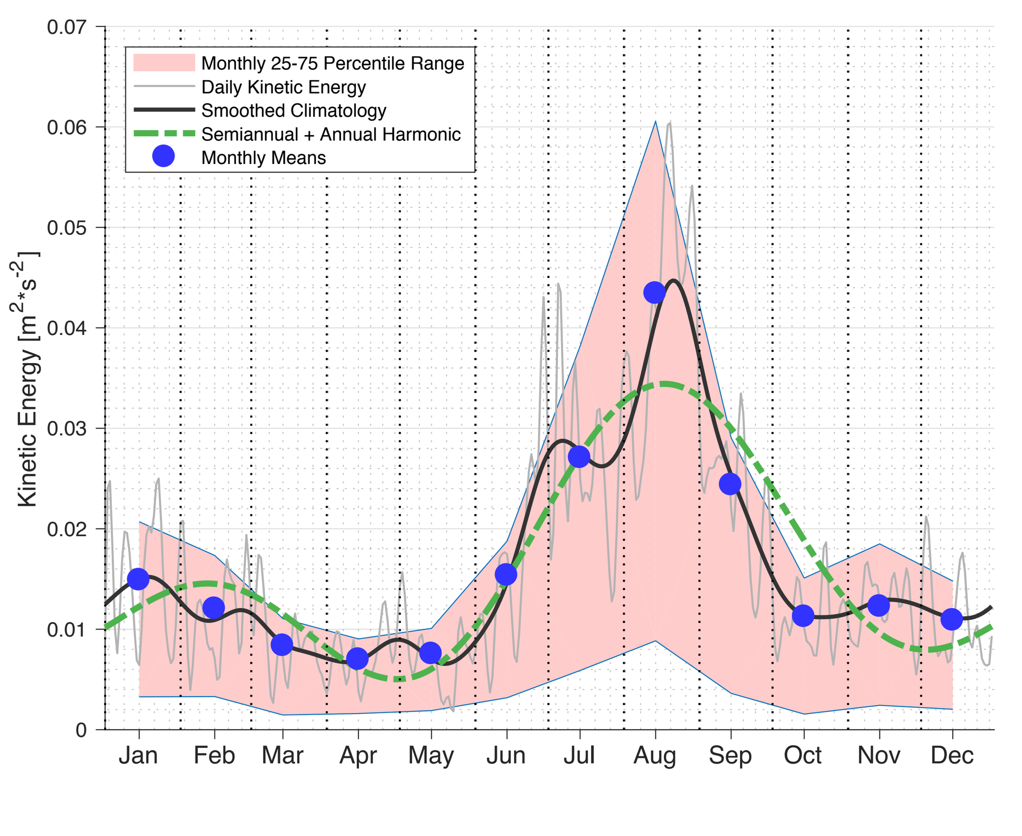
- Based on almost 15 years of equatorial moored velocity data at 23°W, intraseasonal variability is analyzed.
- Near the surface, intraseasonal energy is at its maximum and dominated by TIWs.
- Below the near–surface layer, **downward energy propagation is implied**, according to the linear wave theory, by upward phase propagation.

- Close to the surface, meridional velocity variability occurs in a wide range of frequencies.
- Below 50–100m and **down to about 3000m**, the variability sharpens towards the frequency range from 5–15 cycles per year.



Periodogram of meridional velocity at 23°W from moored observations (2001-2016). The orange box marks the intraseasonal frequency range (approx. 5-15 cycles per year).

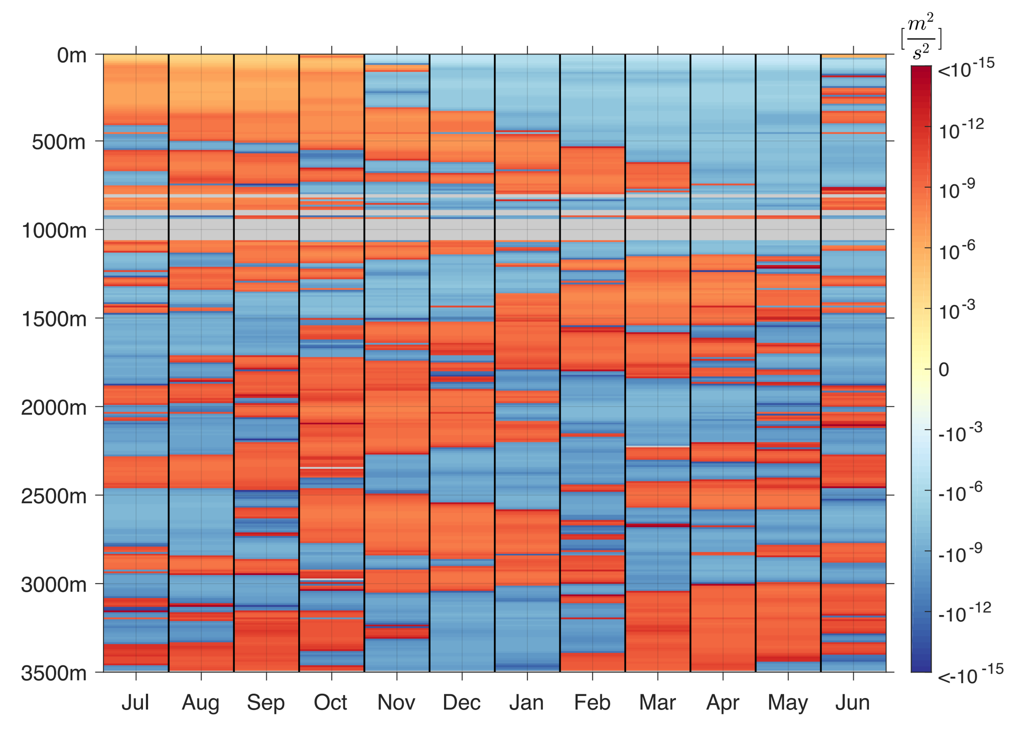
Seasonal Cycle



Daily and monthly climatology of intraseasonal specific kinetic energy of the meridional flow averaged over the near-surface layer (20-50m).

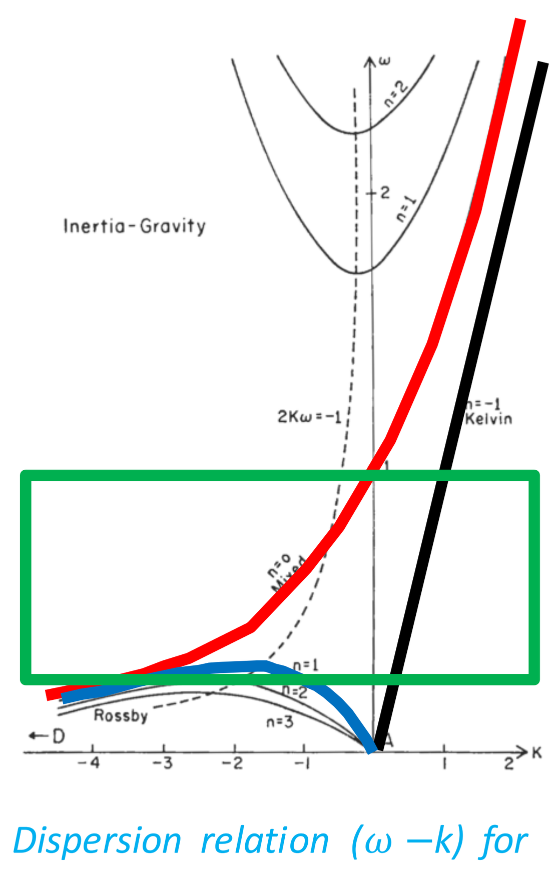
- The intraseasonal variability of the near–surface layer meridional velocity (20–50m) is dominated by an **annual intensification of specific kinetic energy** $(^1/_2\, v'^2)$ **from July to September.**
- A linear combination of a semiannual and an annual harmonic cycle is able to explain a large fraction of the observed seasonal variability.

- In boreal summer, positive anomalies of intraseasonal energy start to propagate downward and reach a depth of about 800m during boreal winter.
- At larger depths, observations indicate **interference of downward and upward energy propagation.**

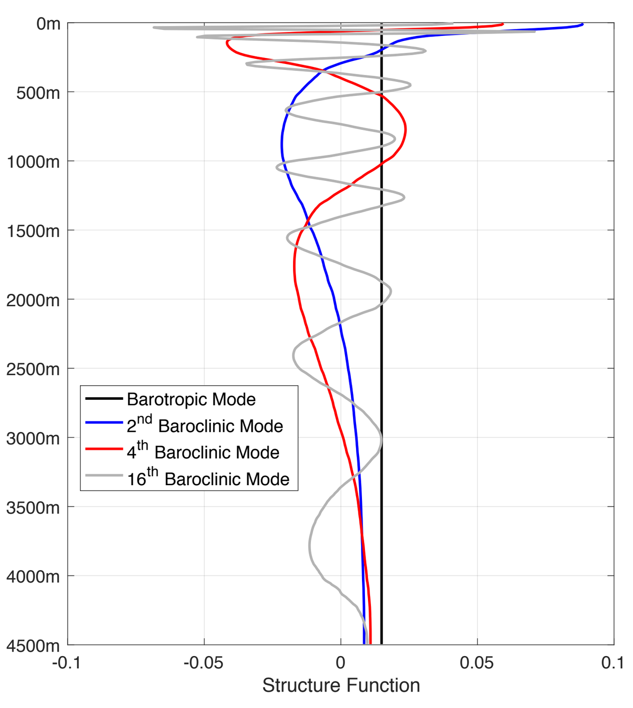


Monthly climatology of anomalous (with respect to the mean) intraseasonal kinetic energy over depth (fitted with an annual and a semiannual harmonic cycle at each depth). Months and depths with insufficient data coverage are marked grey.

Mode Analysis



Dispersion relation (ω –k) for waves on an equatorial β – plane. The dashed line connects the extrema and n represents the meridional mode. Taken from Cane & Sarachik (1976).

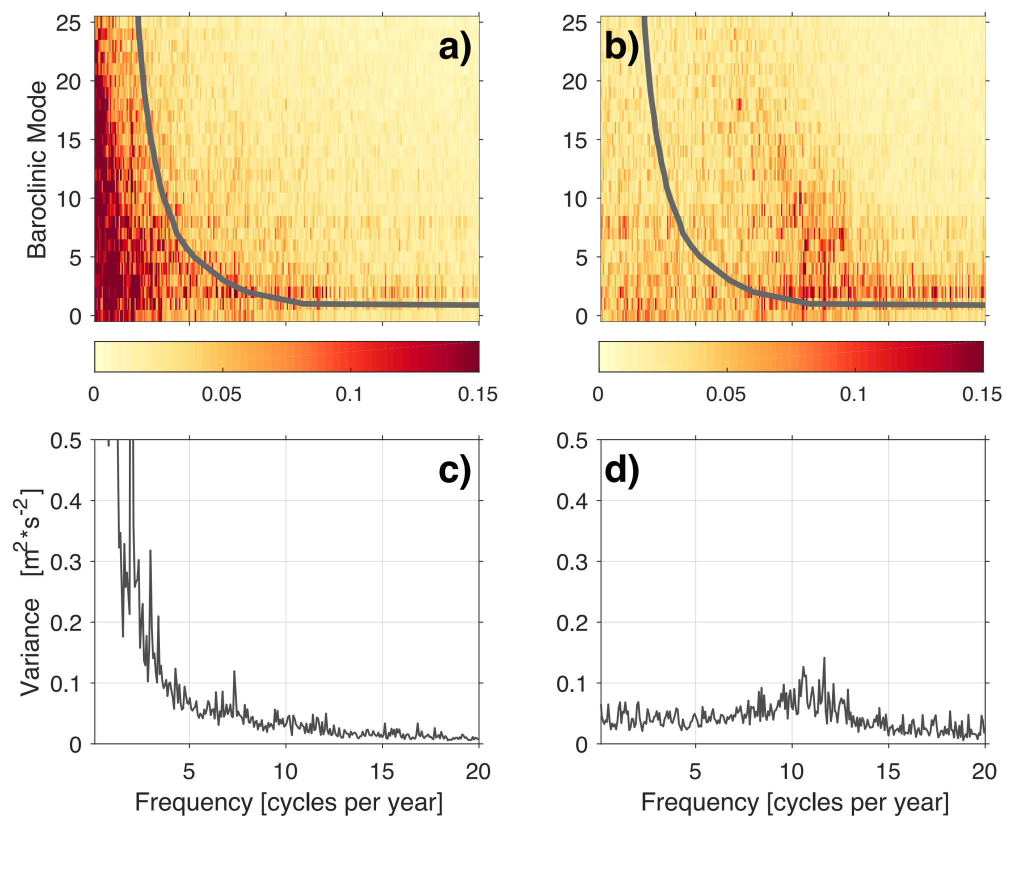


Vertical mode structure function of the barotropic and chosen baroclinic modes for H=4500m. They are normalized as follows (with $\hat{p}_n$ representing the n^{th} vertical mode structure function):

$$\frac{1}{H}\int_{-H}^{0} \hat{p}_n^{\,2}\, dz = 1$$

- At the equator, the dispersion relation allows for three different wave types within the **intraseasonal frequency band**: **Kelvin**, **Rossby** and **Yanai** waves.
- A set of vertical mode structure functions is used to decompose both moored velocity components (e.g. *Claus et al., 2016*).

- Zonal velocity amplitudes are largest at low frequencies.
- The meridional velocity spectrum peaks in the intraseasonal band and above the cut–off frequency of equatorial Rossby waves suggesting that **Yanai waves dominate the DEIV**.



Amplitude spectrum [ms⁻¹] of zonal (a) and meridional (b) velocity with the cut-off frequency of equatorial Rossby waves (grey lines) superimposed; variance spectra (c,d) derived by summing the squared amplitude spectra (a,b) over all baroclinic modes.

References:

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